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Demonstration of High Data Rate and Medium Data Rate VSAT Communications using the Global Broadcast System (GBS) Transponder

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13. ABSTRACT *(Maximum 200 words)*

During the months of November and December 1996, the Naval Research Laboratory (NRL) successfully demonstrated medium data rate (160 kbps) and high data rate (1.288 Mbps and higher) satellite links using transponders for the Global Broadcast System (GBS) and Joint Broadcast System (JBS). The demonstration was conducted at NRL with assistance from the Defense Information Systems Agency (DISA) and the Operational Support Office (OSO). Direct sequence spread spectrum (DSSS) links and conventional QPSK (1.544 Mbps) links were established on a satellite transponder that was simultaneously occupied with the GBS broadcast originating at the GBS earth station terminal at the Pentagon. The DSSS signal was transmitted using a very-small-aperture-terminal (VSAT) having a 24" articulated antenna, and was received by the 3.7 m earth station. The conventional QPSK signal was transmitted from the earth station and was received by the VSAT. Test results showed that the satellite transponder could support the broadcast, a conventional QPSK signal and a DSSS signal simultaneously. Bit error rates in the 10^{-6} to 10^{-8} range were achievable.

This report addresses the tests conducted and the potential that a VSAT system, used either in conjunction with- or independent of the GBS/JBS systems, could have for other satellite-based wireless network applications.

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Demonstration of High Data Rate and Medium Data Rate VSAT Communications using the Global Broadcast System (GBS)Transponder

I. Introduction

The Global Broadcast System (GBS) provides a mechanism for delivery of unprecedented amounts of intelligence information to tactical commanders of all services in the field and afloat. The broadcast is conducted under the auspices of the Joint Program Office and was initially implemented by the Operational Support Office (OSO). It was subsequently transitioned to the Defense Information Systems Agency (DISA) and currently uses leased commercial Ku-band satellites and fixed Government-owned uplink terminals. Receiving terminals located at tactical headquarters and on board ship use commercial off-the-shelf (COTS) hardware with 1 meter parabolic receiving antennas. Access to the broadcast is limited to coverage areas within the footprint of the satellite.

Although GBS provides a far superior quantity of data as compared to previous dissemination systems, commanders are limited by the lack of an effective way to request the broadcast of information specific to their immediate needs. This limitation is in part due to receiving terminal equipment configurations which do not incorporate upconverters, power amplifiers and other components needed for transmitting. It is exacerbated by the performance of the 1 m receiving antenna, whose wide beamwidth can illuminate multiple, closely spaced geosynchronous satellites resulting in interference to other satellite users. It had been submitted by NRL and others in the Defense community that the GBS transponder could be used to support a full duplex interconnected network of Very Small Aperture Terminals (VSATs) in addition to providing the current broadcast capability. This VSAT network could support a multitude of data types (network data, voice, conference video, telemedicine, etc.) and classification levels in a bi-directional manner at various data rates and link the shipboard or wireless mobile users local area networks to the terrestrial networks currently available within DoD.

The Naval Research Laboratory (NRL) has successfully used commercial DSSS modems on small aperture terminals that have been employed both in sea-based and land-based applications. DSSS modulation spreads the transmitted energy over a wide bandwidth, as much as 30 times the information rate. Specifically, the DSSS modems used in the NRL tests spread a high data rate (HDR) signal operating at 1.288 Mbps over 41 MHz of bandwidth, and a medium data rate (MDR) signal operating at 160 kbps over 6 MHz of bandwidth. The use of this modulation reduces the magnitude of spectral energy as seen by adjacent satellites, thereby reducing interference to other users. Additionally, the DSSS modems, and future incarnations based on CDMA technology, enable processing gain [1] to be employed for overcoming the low signal-to-noise ratio established on the uplink by using a VSAT terminal (with an EIRP smaller than that for a larger antenna).

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During November and December of 1996, NRL demonstrated the potential for MDR and HDR communications backchannels using satellites which carried the GBS signal and the signal of its European counterpart, the Joint Broadcast System (JBS). MDR and HDR DSSS signals and a narrowband QPSK signal operating at 1.544 Mbps, were transmitted over a satellite transponder that was simultaneously occupied with the GBS broadcast signal. The DSSS signal was transmitted from a specially configured VSAT with a 0.6 m articulated antenna, to a fixed 3.7 m earth station. The QPSK signal was transmitted from the 3.7 m earth station and received by the VSAT; both terminals were located at NRL.

As part of the ongoing NRL VSAT development efforts, NRL normally addresses all 7 layers of the network model, with special emphasis on layers 1 through 3. The VSAT network solutions developed by NRL routinely support TCP/IP data traffic and applications. Additionally NRL has begun to experiment with Asynchronous Transfer Mode (ATM) over the VSAT network. Previous work by NRL, not covered as part of this report, has demonstrated the ability to route network data between local area networks (LANs) over a VSAT network. Classified and unclassified data, consisting of standard Internet applications, desktop video-teleconferencing, and JMCIS data, have been routed over a satellite-based WAN between the VSAT system operating at a New SSN Open Systems Critical Item Test (OSCIT) facility at NUWC, CT and the Naval Ocean Processing Facility (NOPF) in Dam Neck, VA. NRL also has an active program that has successfully deployed an ocean going buoy networked at T1-class speeds to terrestrial networks via the VSAT system. [2,3,4,5,6]

This report addresses access to the physical layer (including satellite transponder), bit error rate testing, and the results that were obtained. It is anticipated that for a GBS/JBS deployment, a 1 m receive-only system would be modified to enable bi-directional communication. The results obtained and described below using the 0.6 m VSAT would be expected to improve if a 1 m antenna was substituted. Potential applications for this technology are also presented.

II. Test Configuration

The GBS backchannel evaluation required a system configuration with three earth stations as depicted in the diagram shown in Figure 1:

1) GBS Broadcast Facility;
2) NRL's custom VSAT configured for full duplex operation; and
3) A 3.7 m earth station.

Terminal #1, the GBS Broadcast Facility, was located at the Pentagon was operated by personnel from DISA. Terminals #2 and #3 were operated by NRL with support and guidance from personnel of the OSO, and were located on Building 260 at NRL.

DISA provided the GBS broadcast uplink using Terminal #1, and verified the integrity of the GBS downlink video signal using a 1 m receiving antenna comparable to the JBS receiving terminals used in Europe. During the December testing, the GBS signal was monitored at NRL with an identical 1 m terminal.

The VSAT, identified in Figure 1 as Terminal #2, transmitted the DSSS uplink signal and received narrowband QPSK transmissions from Terminal #3 over the same satellite transponder. Terminal #3 received the DSSS signal and transmitted the QPSK signal through the satellite to Terminal #2. Bit error rate (BER) tests were conducted alternatively on the DSSS and the QPSK links, using a Fireberd 6000 at each end of the link.

In addition to bit error rate, a numerical parameter indicative of the received signal strength was provided by the receiving system at the two GBS receive terminals. This parameter, hereafter referred to as the GBS SS (SS for signal strength), is a figure of merit for reception of the broadcast after processed, rather than an RF or IF measurement. The actual RF received signal strength can be obtained from the GBS SS value through the use of a look-up table provided by the GBS receiver manufacturer.

Satellite services for the testing in November were provided by Orion Atlantic on the Orion-1 satellite, transponder #22. This transponder is used to provide service for the JBS to Europe from CONUS. Satellite services for the December testing were provided by Hughes on the satellite SBS-6, transponder #2. This transponder is used to provide GBS service in CONUS, and receives the uplink signal from a DISA terminal at Ft. Monmouth, NJ.

Since the JBS signal characteristics are identical to those of the GBS signal, GBS is used to identify the generic broadcast for the remainder of this report.

A. VSAT Station

The VSAT terminal was comprised of a Sea-Tel TVRO antenna system with a 0.6 m diameter antenna that was specially modified by NRL and configured with both transmitting and receiving subsystems. A block diagram of the configuration is shown in Figure 2. The system includes a downconverter and QPSK modem to demodulate the narrowband signal being transmitted to the satellite from terminal #3. It also includes the DSSS modem with a special upconverter to convert the modulator output from 2.4 GHz to Ku-band for transmission.

This configuration was used for all testing in November and December, using the Orion and SBS-6 satellites, respectively. The DSSS modem shown in Figure 2 represents either the high data rate (HDR) modem transmitting at 1.288 Mbps or the medium data rate (MDR) unit operating at 160 kbps, depending on which data rate was being tested.

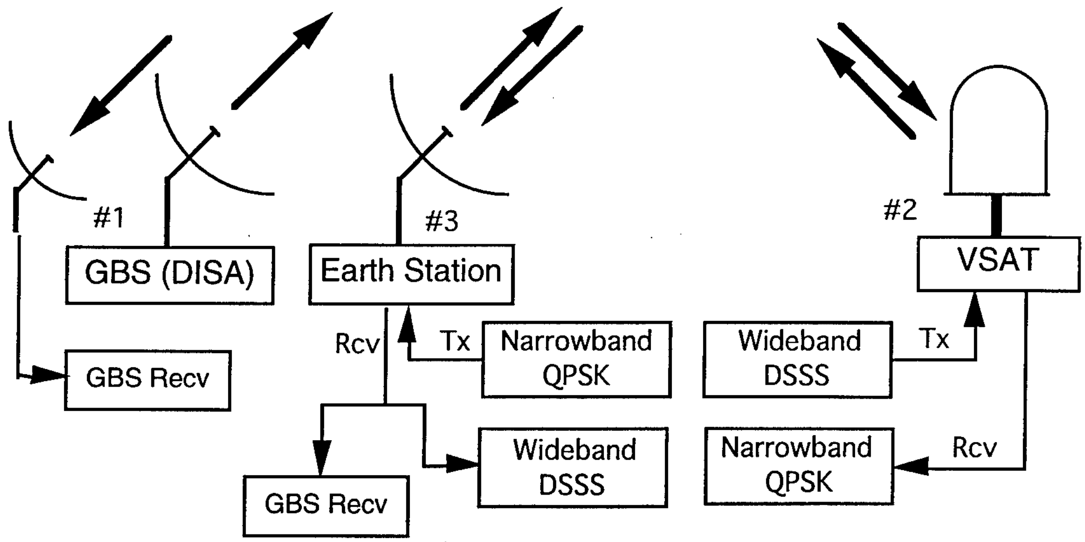

Figure 1: GBS Backchannel Test Configuration. The GBS system loads the transponder and monitors the GBS broadcast while the other two stations use the same transponder for narrowband and wideband link testing. The GBS signal signal strength was also monitored at Terminal #3 at NRL.

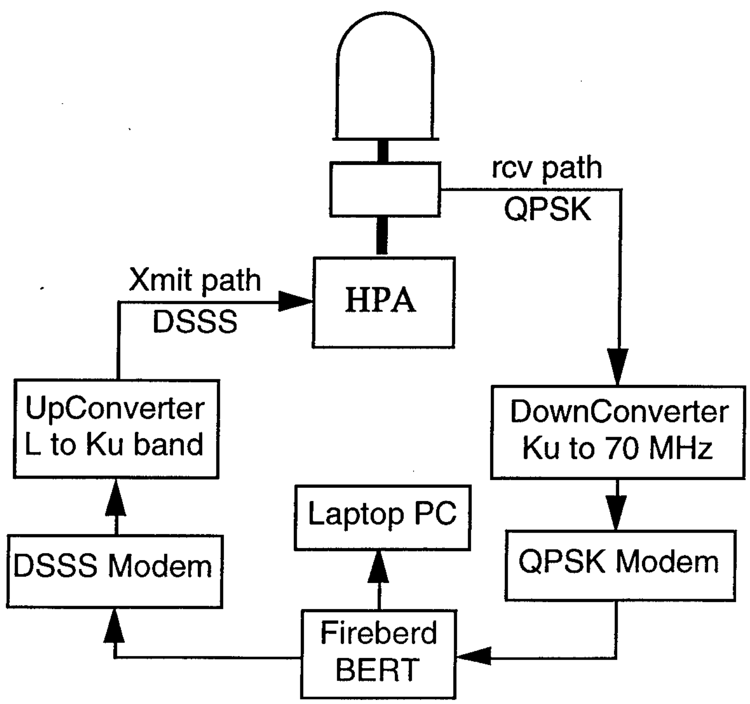

Figure 2: VSAT Terminal Configuration. The Bit Error Rate Tester (BERT) was moved from the uplink to the downlink path, alternatively acting as the data source and the analyzer.

B. Earth Station - November 96

A 3.7 meter earth station was used for transmitting the QPSK signal and receiving both the GBS broadcast and the DSSS signal. A low noise amplifier (LNA) was mounted at the receive antenna feedpoint to provide good receiving system noise performance, and the transmit and receive paths used low loss waveguide and coaxial cable, respectively, to connect the antenna to the equipment. The BER test set (BERT) was used on both the transmitting and receiving paths, acting as a source and analyzer, respectively to analyze link performance in each direction. Figure 3 shows the equipment configuration of the earth station.

A GBS receiver provided a visual indication of broadcast signal integrity, as well as the GBS SS. The received GBS signal and GBS SS were monitored to gauge the effects of additional loading of the satellite transponder by the test signals, as well as effects from rain fading. The DSSS modem in Figure 3 was either a HDR or MDR (1.288 Mbps or 160 kbps respectively) modem, consistent with the one being used in the VSAT configuration.

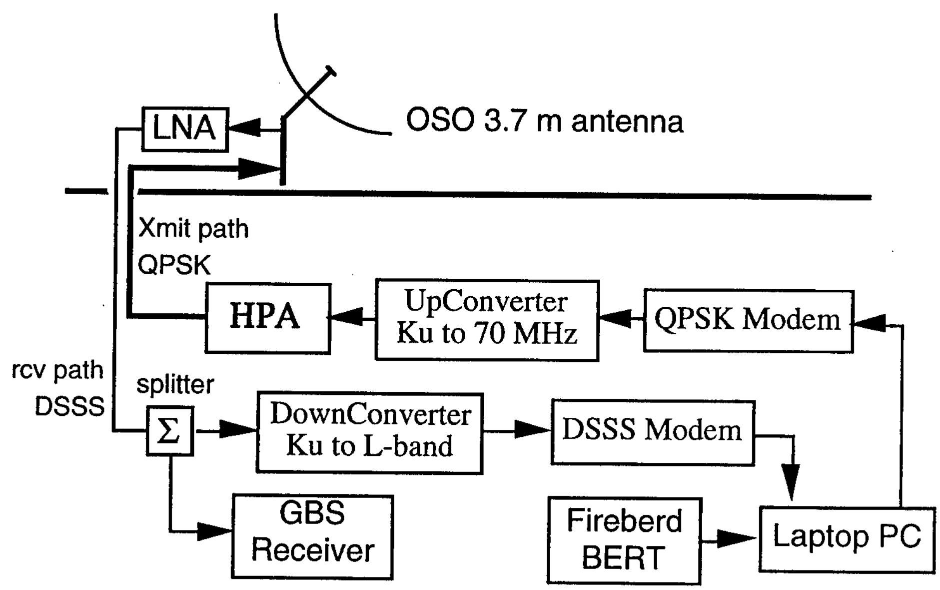

Figure 3: Earth Station Terminal Configuration. The Bit Error Rate Tester (BERT) was moved from the uplink to the downlink path, alternatively acting as the data source and the analyzer. The GBS receiver provided a processed signal strength on the GBS downlink.

C. GBS Broadcast Station - November 96

The GBS Broadcasting Station at the Pentagon, represented in Figure 4, consisted of the Broadcast System (Transmitter) and an independent 1 m GBS receive station, as described for Figure 1. The GBS receive station

provided DISA additional visual verification of the effects of added transmit waveforms on the satellite transponder, and of rain fading on the channel.

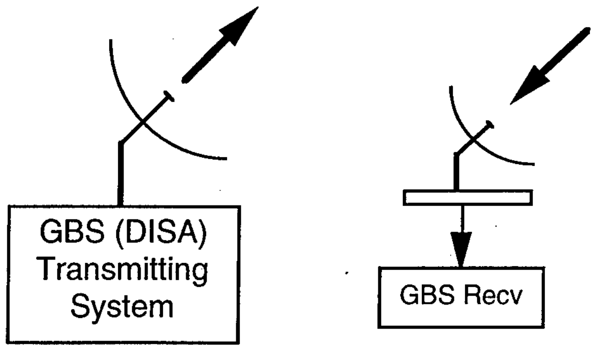

Figure 4: GBS Broadcast Configuration. The GBS transmitter loads the transponder, and the GBS broadcast is monitored off of the smaller (1-meter antenna) terminal.

D. GBS Broadcast & Earth Station - December 96

The GBS broadcast uplink station used in December was located at Ft. Monmouth, NJ. Because operations at this site were unable to monitor the GBS downlink signal, a 1 m (antenna) GBS receive terminal was set up adjacent to the earth station at NRL. A power divider was installed to allow the received GBS signal and additional signals to be monitored on a spectrum analyzer (as shown in Figure 3).

III. Testing and Results

A. November 96 Tests

System checkout was conducted on the VSAT, radiating the HDR DSSS signal at various power levels to establish a link having better than 10^{-6} bit error rate. No other signals were present on the Orion transponder during this checkout. The power level of the GBS broadcast was then increased to its normal operational level on the transponder; this was defined by Orion Atlantic to be 2 dB below the 2-to-1 dB compression point. This operating point is the level at which an increase in power of 2 dB into the transponder results in a1 dB of increase in the transponder output power, and is hereafter referred to as "compression". This condition corresponds to operating the GBS transmitter at 2.5 dB below its maximum output power. With only the GBS broadcast present on the transponder, the GBS SS (as monitored by the GBS receiver with the 3.7 m antenna) was 97. This is equivalent to a received Eb/No of 14.0 dB when using 6/7 rate forward error correction (FEC) coding.

Next, both the HDR DSSS and the GBS broadcast were transmitted through the transponder using the frequency plan shown in Figure 5. The center frequency of the GBS waveform was fixed by DISA, and the DSSS

signal was positioned spectrally to use as much of the available transponder bandwidth as possible, while minimizing interference with the GBS broadcast. There was an overlap of approximately 2 MHz between bandwidths of the DSSS and GBS waveforms, with the DSSS signal occupying a 30 MHz bandwidth, and the GBS using 24 MHz of bandwidth.

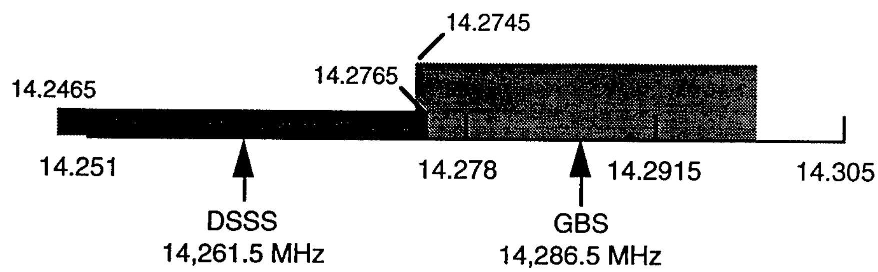

Figure 5 Frequency plan for testing with the GBS broadcast and a 1.288 Mbps DSSS signal.

BER testing was conducted on the DSSS link in this transponder loading configuration and resulted in an average BER of approximately 2.8 10^{-5}, with no error correction or processing on the data stream. The overlap in waveforms did not affect picture quality at either the 1 m or 3.7 m GBS receiver terminals.

The HDR DSSS modems were replaced with the 160 kbps MDR modems and further BER tests were conducted with the GBS broadcast at compression level on the transponder. Two spectral separations, as shown by the frequency plans in Figure 6, were examined. The first frequency plan used a frequency separation of 23.5 MHz between the center frequencies of the two signals, and the second plan used a separation of 16.5 MHz. The second frequency plan placed the DSSS signal adjacent to the GBS waveform to demonstrate that having a signal in close proximity to the broadcast would not degrade performance. BER tests conducted on the DSSS link over a total of 35 minutes showed no errors for either frequency plan and the reception of the GBS broadcast video was unaffected.

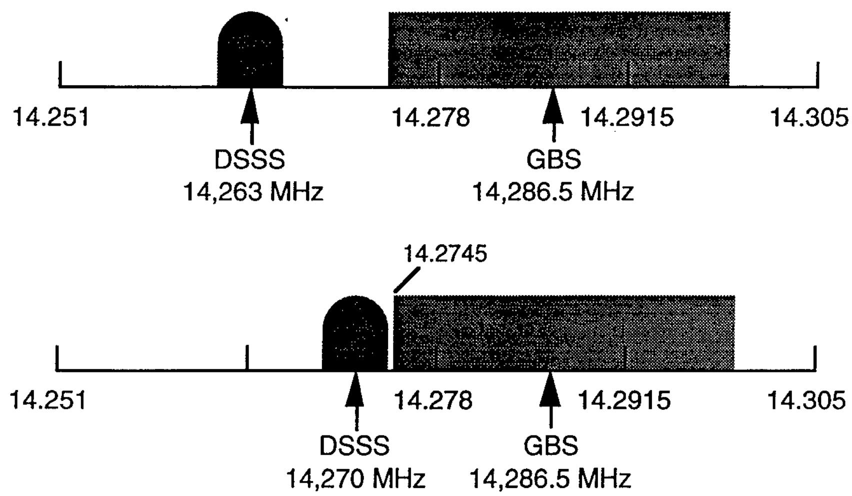

Figure 6 Frequency plans for testing of MDR (160 kbps) DSSS signals in the presence of the GBS signal.

DSSS and GBS with a Narrowband QPSK Signal

The transponder was loaded with the MDR DSSS signal, the GBS broadcast, and a narrowband QPSK signal operating at 1.544 Mbps (with 3/4 rate FEC encoding) as shown in Figure 7.

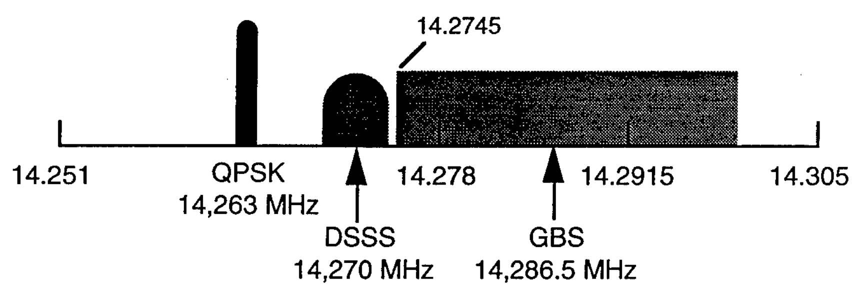

Figure 7. Frequency plan for testing with the GBS broadcast, an MDR DSSS signal and a T1 (1.544 Mbps) QPSK signal.

BER tests were conducted on both the DSSS and the QPSK links with the GBS broadcast operating at compression (as defined previously). No errors were detected on the MDR DSSS link over a 25 minute period. The estimated EIRP of the VSAT transmitting the DSSS during this test was 52.2 dBW. BER test results on the QPSK link, shown in Figure 8, demonstrated a nominal BER of 10^{-6}. Although the exact cause is unknown, the variations may have been due to intermittent performance of the modems. The 3.7 m earth station transmitting the QPSK signal had an estimated EIRP of 64.5 dBW.

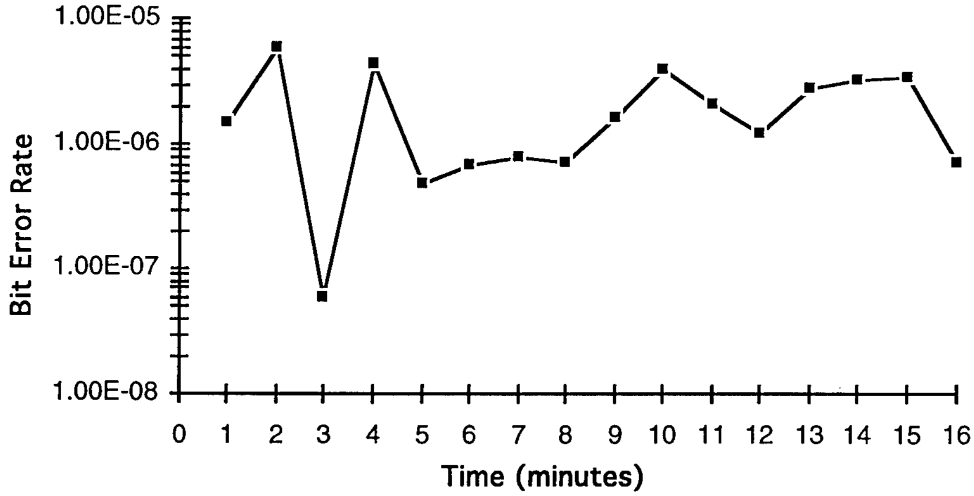

Figure 8: Bit Error Rate (BER) test results for a QPSK T1 (1.544 Mbps) link sharing a 54 MHz Transponder (on Orion 1) with a 160 kbps DSSS signal and the GBS broadcast. QPSK signal is 3/4 rate encoded.

The power level of the GBS transmitter was lowered to 8.5 dB below compression. BER tests were conducted on the QPSK link with both the QPSK signal and the DSSS signal operating at the EIRPs established in the previous test. No errors were observed.

Further testing focused on HDR DSSS link performance. Efforts were complicated by severe thunderstorm activity in the Washington, DC area, which frequently resulted in loss of both the experimental backchannel links and the GBS broadcast itself.

Figure 9 shows the BER performance for the HDR DSSS signal when sharing the transponder with the GBS broadcast. These tests were conducted with the GBS signal operating at a level of 3 dB below transponder compression, and with the EIRP for the VSAT calculated to be 55.8 dBW. Over the course of more than two hours, there were a number of dropouts of both the DSSS signal and the GBS broadcast itself, as well as short blocks of time (1 minute/block) when no errors were detected (these are expressed as a BER of 10^{-8}). The BERs varied from the 10^{-4} to 10^{-8} range, and the poorer BER performance correlates with rain activity in the area, affecting both the Pentagon and NRL sites. BER test results are shown in Figure 9. Instances where BERT synchronization was lost are indicated by an asterisk. Once synchronization was re-established, the BERT would continue its test. During the test period, the GBS SS measured at the 1 m terminal varied from 82 (equivalent to an Eb/No of 11.4 dB) to zero.

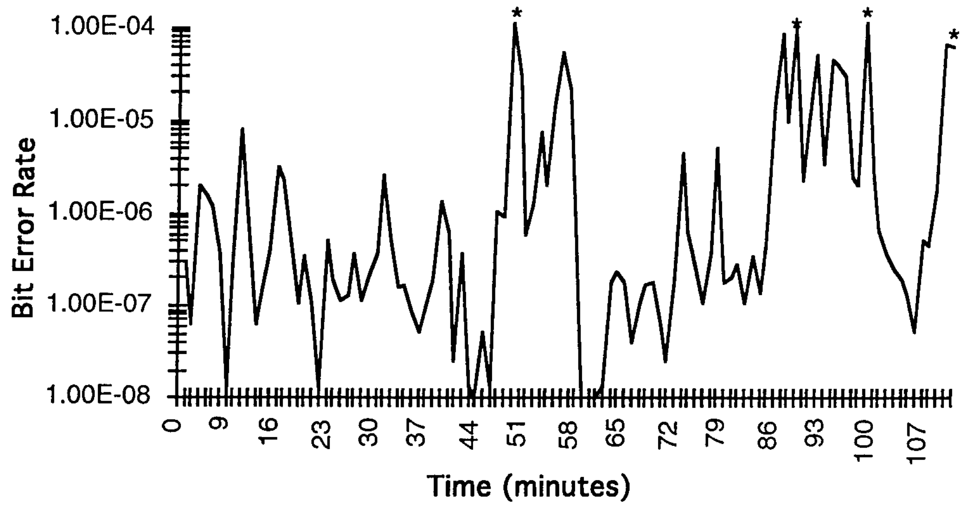

Figure 9: Bit Error Rate (BER) test results for a DSSS (1.288 Mbps) link sharing a 54 MHz transponder with the GBS broadcast. Synchronization loss/interruptions in service during the test due to heavy rains are indicated by an "*". Blocks of zero errors are expressed as the BER of 1E-08.

The tests were repeated with the GBS power output increased to a level of 1 dB below transponder compression and using the same transmitter power on the DSSS link. There was still heavy cloud cover in the area and some intermittent light rain, but there were no interruptions in the GBS broadcast or in BERT synchronization. The GBS SS measured at the 1 m terminal varied from 52 to 61 (or Eb/No's of 6.8 to 7.9 , respectively). The BER on the DSSS link is shown below in Figure 10. BERs were in the 10^{-5} to 10^{-6} range but the large fluctuations visible in Figure 9 are not present.

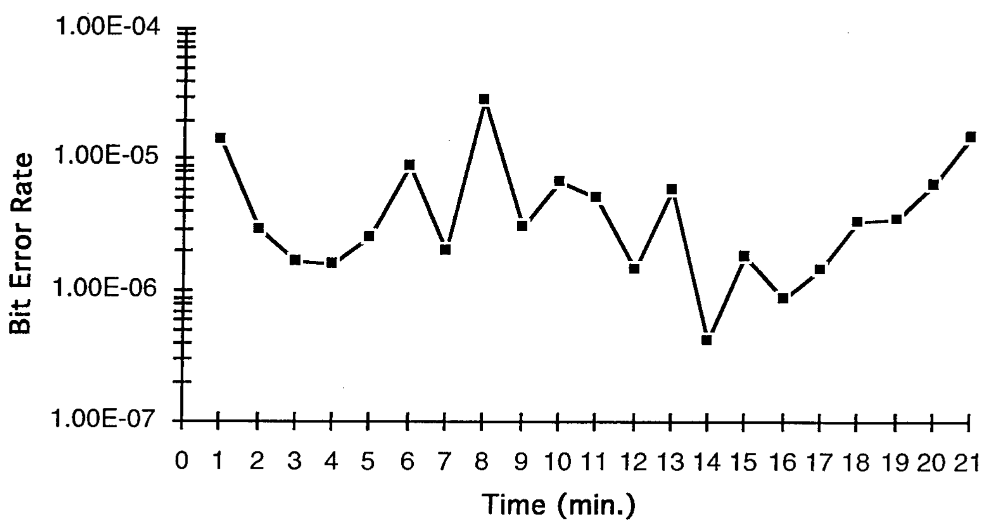

Figure 10: Bit Error Rate (BER) test results for a DSSS (1.288 Mbps) link sharing a 54 MHz transponder with the GBS broadcast. Light rain was present during this test.

GBS Performance Tests

To determine how the GBS video integrity was affected by the introduction of the various waveforms when sharing the transponder, DISA measured the GBS SS parameter at their 1 m terminal for a variety of conditions of transponder loading. The results are shown in Table 1 below and apply when operating the DSSS modem at 160 kbps:

	GBS SS	Eb/No (6/7 rate)
i) GBS, QPSK and DSSS signals:	71	9.5
II) GBS only:	80	11.1
III) GBS and QPSK signals:	72-73	9.6 - 9.8
iv) GBS and DSSS signals:	79	10.9

Table 1: GBS performance for varying transponder loading

It is worthy to note that the presence of the DSSS signal has less impact on the GBS link performance than does the presence of the QPSK signal. This occurs despite the wider bandwidth of the DSSS signal.

Using GBS SS (and picture integrity) as determinants, the minimum operating output levels for both the 3.7 m and 1 m (standard) terminals were determined. It is difficult to determine these levels conclusively because of the variance in path loss (for both the uplink and downlink) over the course of a day, even in stable weather conditions. Table 2 below lists the power amplifier (PA) output, which was recorded at the Pentagon broadcast site, and transmitter backoff relative to the maximum possible output of the GBS transmitter (note that compression in the transponder occurred with the GBS transmitter backed off by 2.5 dB). The GBS SS was taken from the 1 m receive terminal at the Pentagon, and the carrier-to-noise ratio at NRL was estimated using a spectrum analyzer that was receiving the RF downlink from the 3.7 m earth station. The weather was cloudy with no precipitation, and data was taken after sunset at approximately 1830 hrs local time. Table 2 shows that the minimum output power from the GBS transmitter required to close the link with a 1 m terminal was 8.5 dB below the maximum power output of the GBS transmitter. This was 6 dB below the compression level at the transponder.

PA out (W)	Backoff (dB)	NRL GBS SS	DISA GBS SS	C/No@NRL	Comments
-	13.0	-	-	9.3	
-	12.5	35-36	-	9.4	bad video @NRL
-	12.0	38-39	-	9.6	good video @ NRL
19.4	11.0	50-51	-	-	
-	10.0	60	-	11.9	
-	9.0	70	-	12.6	bad video @ DISA
29.3	8.5	74-75	42-43	13.2	good video @ DISA
-	8.0	77	46	13.7	

Table 2: GBS Performance for varying transmitter output

In Table 2, the video receiver produced excellent quality video to a point. However, the video quality degraded very quickly once the signal-to-noise ratio reached the threshold value. When good quality video was observed, all higher power transmitter output levels also produced good video. The threshold Eb/No for good quality video was found to be approximately 5.4 dB (from a GBS SS of 42-43) when using the 1 m receiving antenna. This is achieved when the GBS broadcast transmitter output is approximately 6 dB below the normal operating level. When using the 3.7 m antenna, the threshold Eb/No for good video was approximately 4.81 dB, at a GBS SS of 38-39.

Next, with the GBS transmitter broadcasting to the satellite at a backoff of 8 to 8.5 dB (5.5 to 6 dB below transponder compression), additional signals were brought up and the GBS SS was checked for the following transponder loading scenarios listed in Table 3.

GBS Transmitter Backoff (dB)	Signals Present	NRL SS (3.7 m)	DISA SS (1 m)	DISA Eb/No (dB)
8.5	GBS,DSSS	73	42	5.33
	GBS,QPSK	69-70	39	"tiled"
	GBS,QPSK,DSSS	67	38	"tiled"
8.0	GBS	-	47	6.04
	GBS,QPSK	72-73	41-42	5.25
	GBS,QPSK,DSSS	71	39	4.9

Table 3: Establishing minimum acceptable GBS Performance

Note that the video signal from the GBS 1 m receiver at DISA was generally acceptable for transponder loading scenarios with 8 dB backoff in GBS transmitter power. The term "tiled" in Table 3 refers to the initial degradation of the video signal where segments of the picture are not refreshed as quickly as others. We can speculate that for stable (but not ideal) weather conditions, the GBS video broadcast could operate successfully with both a reduced GBS transmit power and some additional loading on the transponder from both narrowband and wideband signals.

B. December 96 Tests

Further backchannel feasibility testing was conducted in December, using the Hughes SBS-6 satellite. The Hughes transponder used was similar in performance to the Orion Atlantic transponder used in November (e.g., the G/T for both was ~5 dB/°K), but had only 37 MHz bandwidth available. Due to this narrow bandwidth, the MDR DSSS modem (with a 6 MHz wide spread) was the only spread spectrum modem that could be used. Equipment configurations for the VSAT and the 3.7 m terminal were the same ones used in previous tests in November.

As these tests were conducting using an operational broadcast, all results are with the GBS signal "saturating" the transponder.

The frequency plan for testing is shown below in Figure 11. BER tests of the MDR DSSS link generally show bit error rates better than 10^{-6}. Figure 12 depicts the results. During testing, the sky had heavy cloud cover and seemed to have an effect during the latter part of the test period. However, for the first eight minutes no errors were detected (expressed in Figure 12 as a BER of 10^{-8}). The EIRP of the VSAT during this test was estimated at 54.3 dBW.

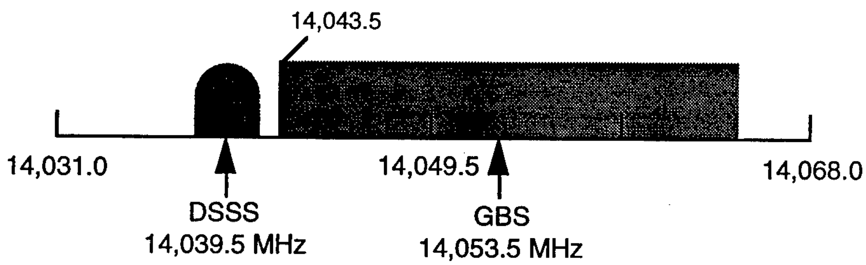

Figure 11. Frequency plan for testing with the GBS broadcast and a MDR DSSS signal on the SBS6 satellite, transponder #2.

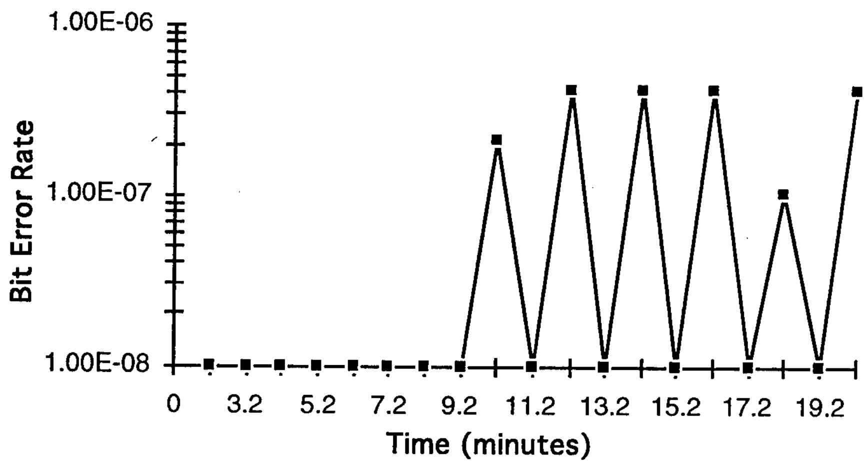

Figure 12: Bit Error Rate (BER) test results for a DSSS (160 kbps) link sharing a 36 MHz Transponder (SBS#6) with the GBS broadcast. Conditions were very cloudy, but no preciptation. Blocks with zero errors were expressed as 1E-08.

A second series of tests was conducted with the GBS broadcast sharing the transponder with the DSSS MDR link and a QPSK signal operating at 1.544 Mbps, as shown in Figure 13. The BER test results of the DSSS link, as shown in Figure 14, show poorer overall performance as compared to previous test, but performance that is slightly more consistent over the test period. The measured GBS SS on the 1 m terminal was 71, but later dropped to 68, for Eb/No's of 9.5 and 9 dB, respectively.

Figure 15 shows the BER test results of the QPSK link taken after finishing the DSSS BER tests. Data blocks where no errors occurred are expressed as a BER of 10^{-8}. Initially, performance varies from approximately 10^{-6} to 10^{-4}, but improves for about 8 minutes and then degrades again. Exact reasons for this result are unknown, but it is speculated that equipment problems may have resulted or contributed to this erratic performance. It was also noted that light rain began to fall at the end of the period.

During these tests, the power output of the VSAT on the DSSS link was reduced by 1 dB, for an estimated EIRP of 53.26 dBW. The EIRP of the 3.7 m earth station was estimated at 64.2 dBW.

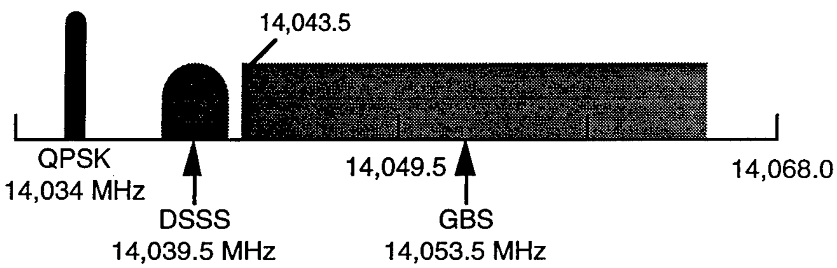

Figure 13. Frequency plan for testing with the GBS broadcast, an MDR DSSS signal and a T1 (1.544 Mbps) QPSK signal on the SBS6 satellite.

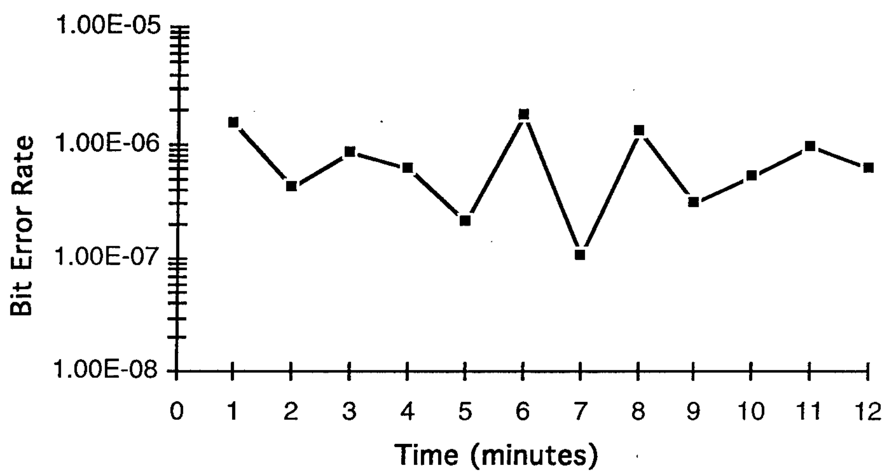

Figure 14: Bit Error Rate (BER) test results for a DSSS (160 kbps) link sharing a 36 MHz Transponder (SBS#6) with a QPSK T1 signal and the GBS broadcast. Conditions were foggy with no preciptation.

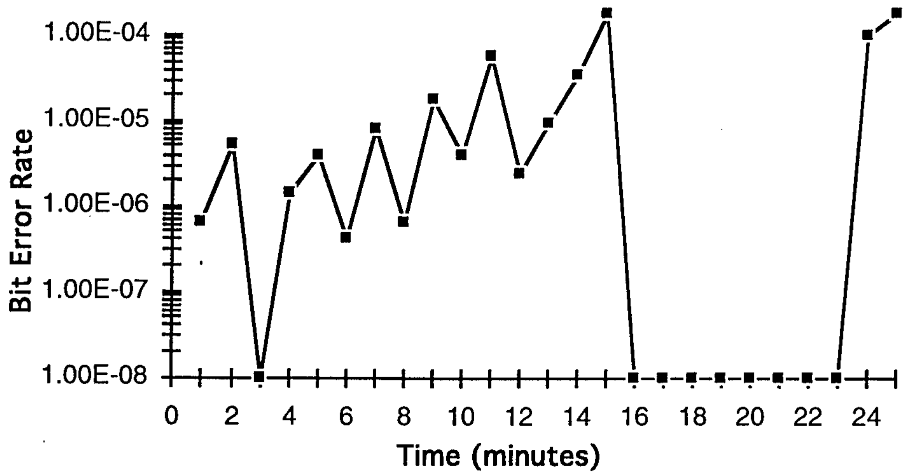

Figure 15: Bit Error Rate (BER) test results for a QPSK (1.544 Mbps) link sharing a 36 MHz Transponder (SBS#6) with a DSSS (160 kbps) signal and the GBS broadcast. The test period ended with some light rain. Blocks with zero errors were expressed as 1E-08.

IV. Conclusions and Potential Applications

Tests conducted by NRL demonstrated the potential for implementation of an orderwire or an outstation reportback capability for GBS, using the same satellite transponder. Tests showed that both the Orion Atlantic transponder used to support JBS, and the Hughes SBS6 transponder used to support GBS, could accommodate both an MDR DSSS signal transmitted from a VSAT as well as a HDR QPSK signal transmitted from the GBS broadcast site and received by the VSAT. Tests showed that:

a) The level of the broadcast output from the Orion transponder can be reduced by as much as 6 dB from compression without impacting the integrity of the received video broadcast at a standard 1 m receive terminal;

b) Bit error rates in the 10^{-6} to 10^{-8} range could be maintained much of the time with MDR DSSS and HDR QPSK signals sharing the transponder with the GBS broadcast, given a 3 dB reduction in the signal power output at the GBS transmitter;

c) Given the wider bandwidth of the Orion transponder, a HDR DSSS transmit capability from a VSAT could be supported. With a 3 dB reduction in the broadcast output power at the output of the transponder, bit error rates on the DSSS link were in the 10^{-6} range; and

d) To the extent that it could be verified, performance of the SBS6 transponder is approximately the same as that of the Orion satellite when supporting MDR and HDR DSSS signals and HDR QPSK signals.

Bit error rate performance, although high when compared to that experienced on fiber optic links, are acceptable on links operating with protocols designed to compensate for transmission errors (e.g., TCP/IP).

The tests conducted imply that a transponder could be employed for full duplex communications and networking on small platforms that currently have access to the broadcast. This could be accomplished totally independent of, or in conjunction with, the broadcast. However, this assumes that both the uplink and the downlink would fall within the same footprint of the satellite antenna beam. This condition exists in CONUS, but not for broadcasts that originate in CONUS and are bound for Europe. An additional transponder would be necessary for transatlantic traffic originating in Europe and destined for CONUS. With the procurement of such a transponder, terminals in the Mediterranean could be modified to support HDR full duplex transmission and networking using TCP/IP data. This capability could be employed to provide HDR access to secure or nonsecure networks in the US as well as providing a mechanism for networking platforms afloat. Additionally such a capability could be used to automate the GBS/JBS data requesting mechanism to enable services similar to what is available today using commercial world-wide-web (WWW) browsers and servers. Such a service would enable warfighters to remotely and interactively (limited as appropriate based on multiple level security) select images for downloading in real-time and could, assuming appropriate security levels, support the ability of the warfighter to inject images into the GBS/JBS system.

In addition to the capabilities a VSAT network would add to the GBS/JBS system, it would also enable small ships and land mobile forces (HMMWV-mounted and similar) access to the kinds of tools and features that currently exist for Challenge Athena-equipped ships. MDR and HDR Ku- and Ka- band VSAT networking solutions using CDMA to minimize interference, enhance link performance, and support multiple access [7], are being investigated. These networking solutions will support multiple applications at various data rates using ATM and TCP/IP over ATM, and will enable the future warfighter an unprecedented level of remote access.

V. Acknowledgments

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